INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-24
Psychrometric Processes-1

with
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Hello I welcome you all in this course on refrigeration and air conditioning today we will take up the psychometric processes in an air conditioning system or on a psychometric chart moving from one state to another state is known as psychometric process.

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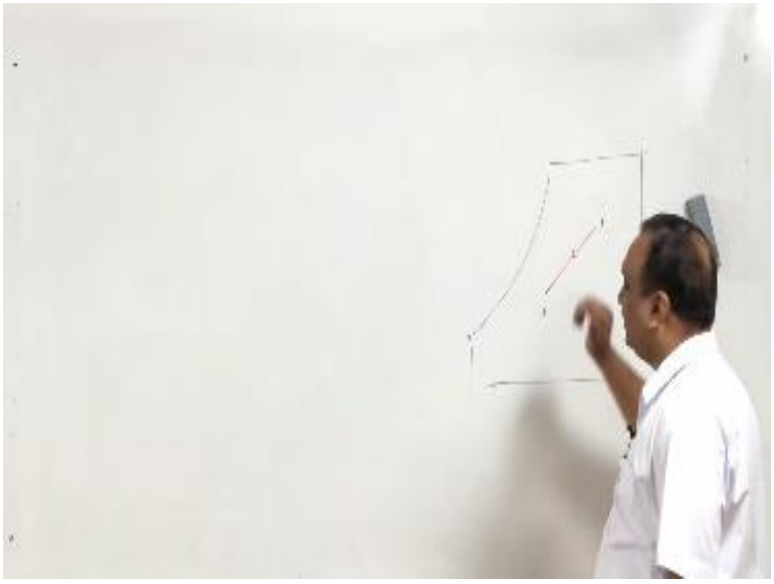

So in a psychometric chart if you are moving from one state to another state it is known as psychometric process during the process we cannot randomly find any path or we cannot go for a

shortest path like this suppose I have to move from state 1 to state 2 I cannot take the shortest path I cannot take the shortest path there are certain restricted paths which we can adopt during the process or for attaining state 2 from state 1 and these paths or processes are known as psychometric processes.

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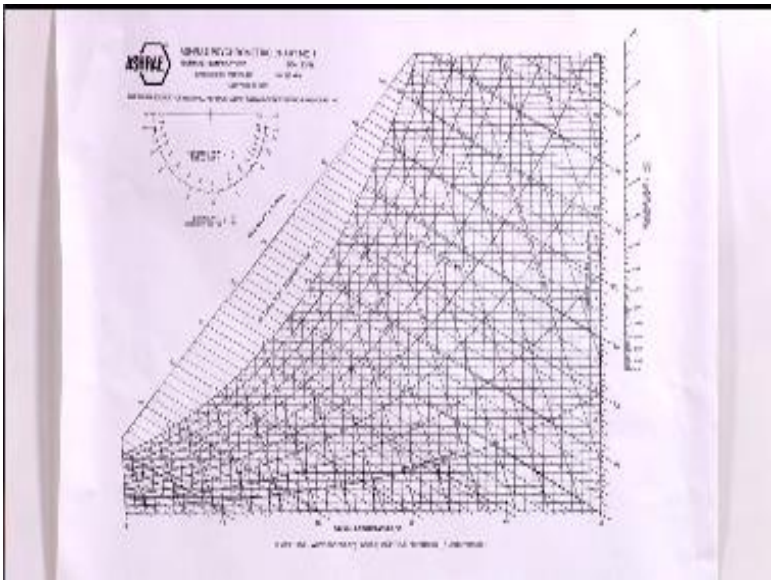

We will discuss these processes one by one and it is better if we use the psychometric chart for this purpose.

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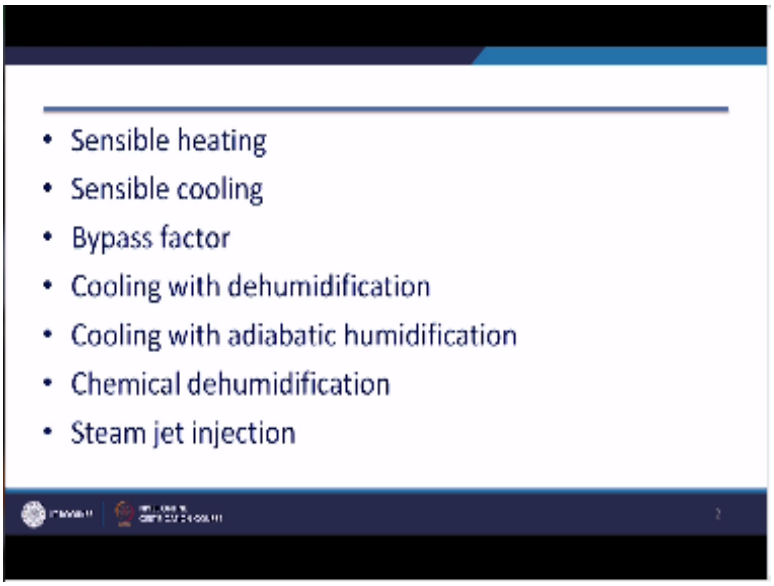

Now let us start with a sensible heating so what is sensible heating.

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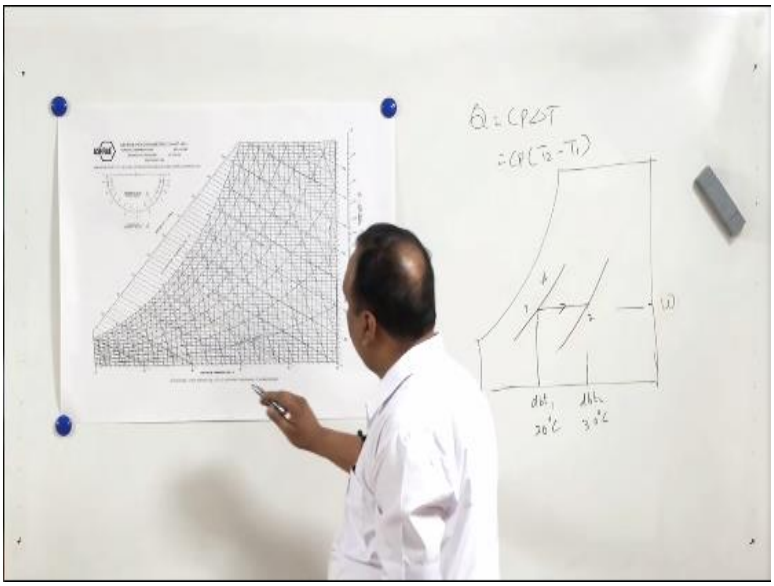

As I am stated earlier the sensible heating is the process of heat addition when there is no fluid tea no phase change of the fluid and the temperature of the fluid rises so if I want to add heat to the air then the moment the heat is added to the air the temperature of air will rise and temperature means here the dry bulb temperature the dry bulb temperature of air will rise and sensible heat is expressed as CPΔT or CP T2 – T1 now here because we have mixture of water and air so at the same time when we are heating the moist air the dryer and the water vapor they will get heated simultaneously.

So directly we cannot use this system analytically also we can find how much heat is added to the system or to the air but on a psychometric chart suppose I say the temperature of air rises from 20 degree centigrade to 25 or 30 degree centigrade and heat is added to the air so first of all 20 degree centigrade with certain relative humidity the air is available and sensible heat is added to the air so sensibly it is added so there is no change in specific humidity or humidity ratio of the air.

So we will follow the horizontal line this is state 1 and then we will get state 2 somewhere here this is a DB T1 this is DB T2 suppose it is from 20 degree centigrade to 30 degree centigrade

now you can see here that specific humidity or humidity ratio has remained constant in this process heating process but the relative humidity has reduced when we are moving in this direction the relative humidity gets reduced.

So in this case also insensible heating the relative humidity got reduced I will draw it again so this is state 1 this is state 2 relative humidity at the state 1 and the relative humidity at the state 2 so relative humidity gets reduced the reverse to is sensible cooling when we are moving from state 2 to state 1 in that case the relative humidity is increasing but specific humidity is remaining constant specific humidity is remaining constant now these processes I like to depict on the psychometric chart 20 degree centigrade.

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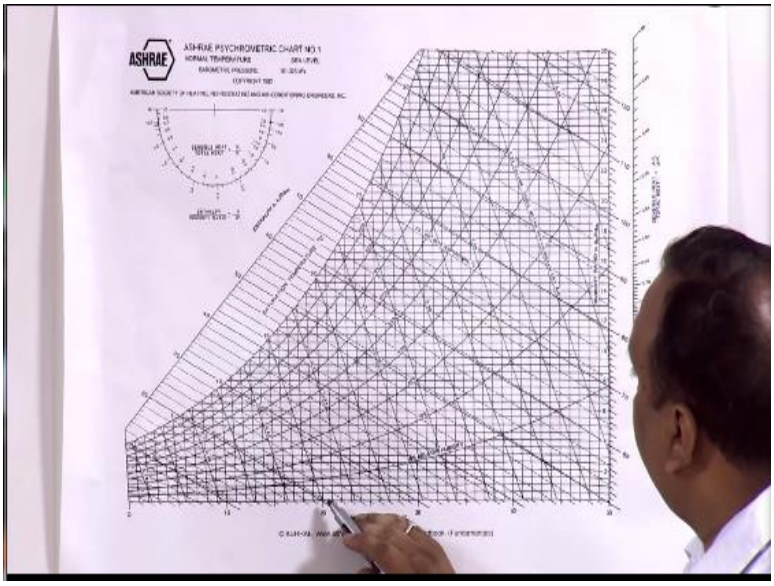

The air is suppose is available at 50% relative humidity so we can place the location here this is the state one and then there is sensible heating sensible heating means is specific this specific humidity or ability ratio is remaining constant and temperature is increased to 30 degree centigrade when the temperature is increased to 30 degree centigrade the relative humidity has reduced from 50% to around 28% air has become tri so sensible heat makes the air dry that is why you must have observed when we run a heater in winter during winters when the heaters are

used the air in the room become dry and it is always advisable when we are using a heat pump or are verse a air conditioning system or we are conditioning system working on the reverse cycle and it is used as a heat pump in that case it is always advisable to keep some wet cloth on the room so that a relative humidity does not reduce drastically suppose in the winters.

Now let us take case of the winters when the temperature is air is available at temperature let us say 10 degree centigrade and relative humidity is 70% here 10 degree centigrade 70% and if I heat this air with the help of heater sensible heating of this here if I do the sensible heating of this air up to let us say 30 or 35degree centigrade or let us say 30 degree centigrade the humidity will reduce to 20% air will become very dry for 20% humidity is quite low humidity and that may cause state of discomfort also in the room so it is always advisable that when you're using a heat pump or heating system.

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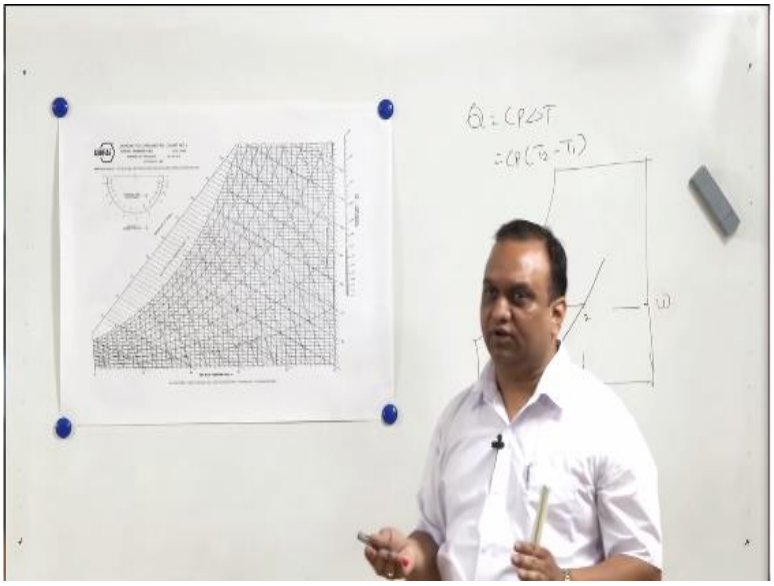

Then have some wet cloth in the room so that the humidity is maintained same is the sensible cooling sensible cooling is the reverse direction suppose air is available suppose.

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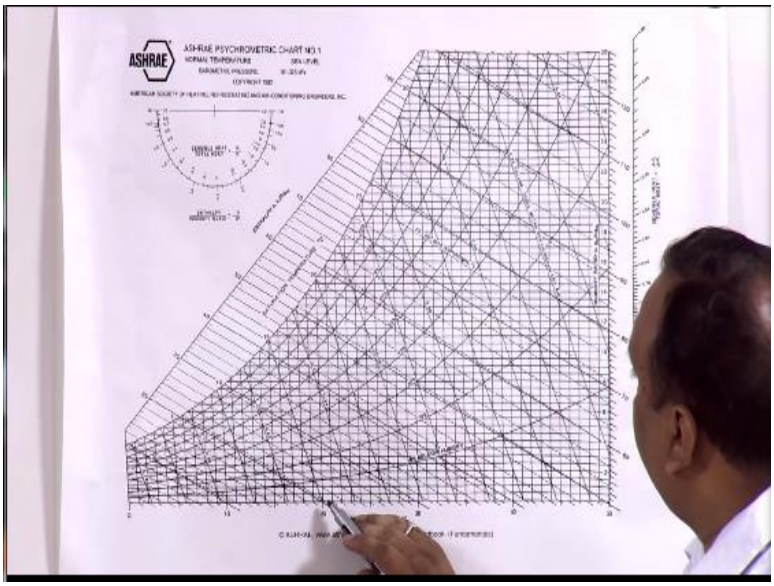

Now a days in during the summer season air is available at 40 degree centigrade and humidity may be around let us say 30% so 40degree centigrade ambient air 30 degree 30% relative humidity if I do sensible cooling of this air up to 25degree centigrade then humidity will be around 70% I may attain temperature of 25 degree centigrade but humidity will be on slightly higher side and if I further cool it to 20 degree centigrade the humidity sorry, sorry the 20 if the temperature is suppose here at Inlet the temperature is 40 % even it is 40 % if I cool this air from 40 % and 40 % relative humidity and 40 degree centigrade temperature.

Then at 25 degree centigrade the humidity may be around 90 % so if in summer season outside air which is available at 40 degree centigrade temperature RH is 40 % that is very normal if I do sensible cooling then relative humidity will be 90%.

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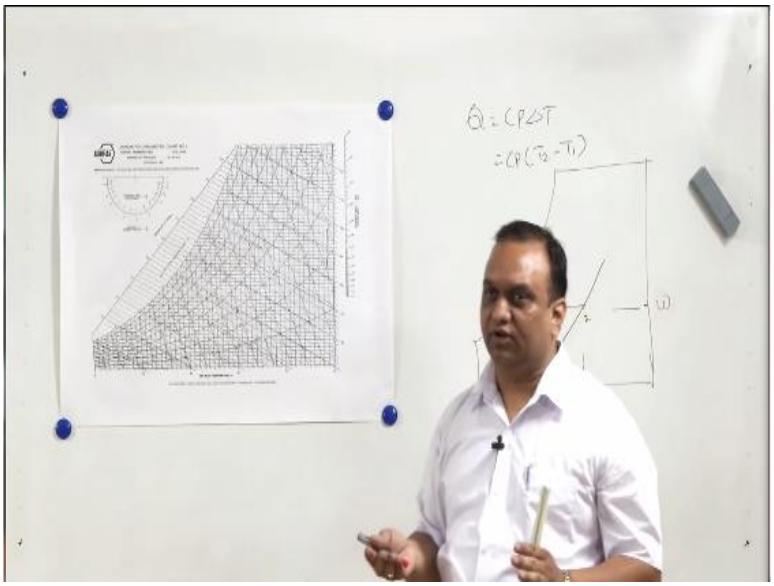

So relative humidity has to be controlled in this process so there are certain other processes where we can control the relative humidity I will discuss those processes later on.

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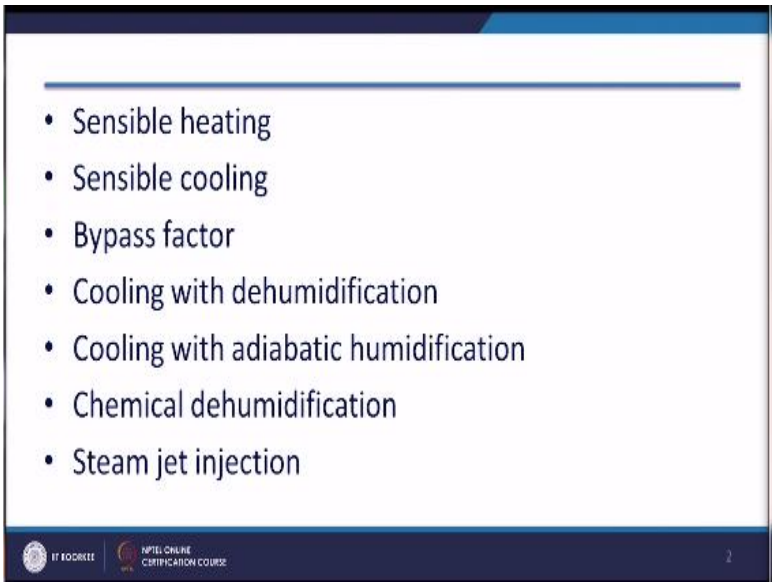

That is pulling with dehumidification in a system on a psychometric chart we are heating from state 1 to state 2.

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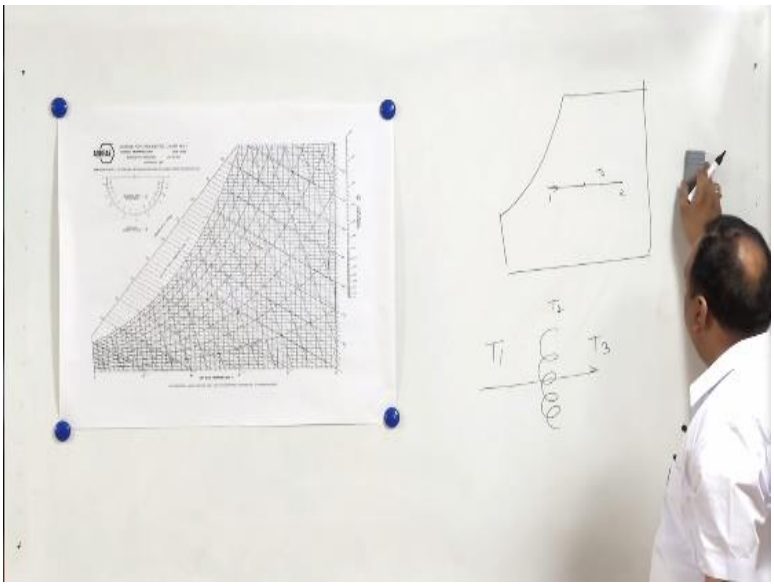

Now how the heating will be done heating will be done we will put a heater or heating coil and air will be blown over this heating coil the heating coil temperature is T2 one to two heating coil temperature is T2 air which is blowing over the heating coil is T1 do you think the air emerging from the heating coil will be a also at T2 it is not possible or it is very difficult to attain such a situation the air which is coming emerging from heating coil will be at a lower temperature T3 I am repeating there is a heating coil which is maintained at temperature to air which is available at T1 at temperature1 T1.

When the air is blown over the heating coil in ideal case it is assumed when it is blown over the heating coil the air will take the temperature T2 but actually it does not happen in actual practice another temperature T3 is attained which is lower than T2 and this is this the temperature difference is this temperature difference the results in the bypass factor we say that why it is called bypass factor we say that part of the air has attained temperature T2 and part of the air is bypassing the coil so if the air is going in this direction at T1 this is at T2 so some fraction of air is getting bypassed and it is bypassed and it is at T1 and the air which is blown over this coil attaining temperature T2.

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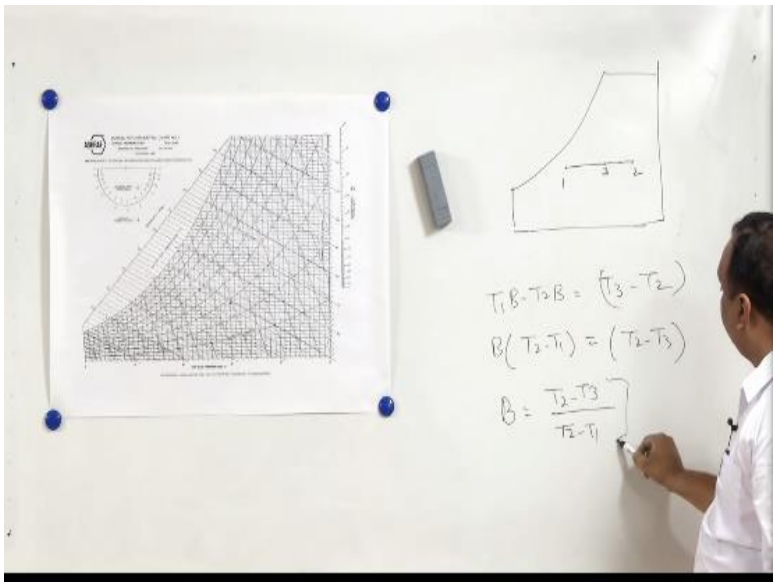

Now if we do the energy balance in this system then I will rub it off so C_PT1 multiplied by B + CpT2 X 1- B = B3 CP T2 CPT3 so here I am repeating there is a coil here at the temperature T1 is blown over the coil current temperature is T2 and the air emerging out of the coil is at temperature T3 it is assumed that the part of the air that is B is bypassed and mixed with the air which is emerging from the coil remaining part of the here in the coil and now we have done the energy balance if you solve this energy balance then you will find that bypass factor is T2 -T 3/Tt2 – T1 because here this CP, CP, CP will be cancelled P1B+ T2 1- B = T3 T1B- T2D = T3- T2 or thr T2- T1 = T2- T3.

On psychometric chart we have shown that this is state 1 state 2 and this is state 3 so bypass factor is T2 - T3 / T2 - T1 it means that is the ideal difference between ideal temperature and actual temperature at the exit of the coil and this is the maximum possible temperature rise in the air this ratio will give the bypass vector closer the point 3 to 2 less is the bypass factor normally when we design the coil bypass factor less than 0.1 is always considered or it is appreciated so this is bypass factor.

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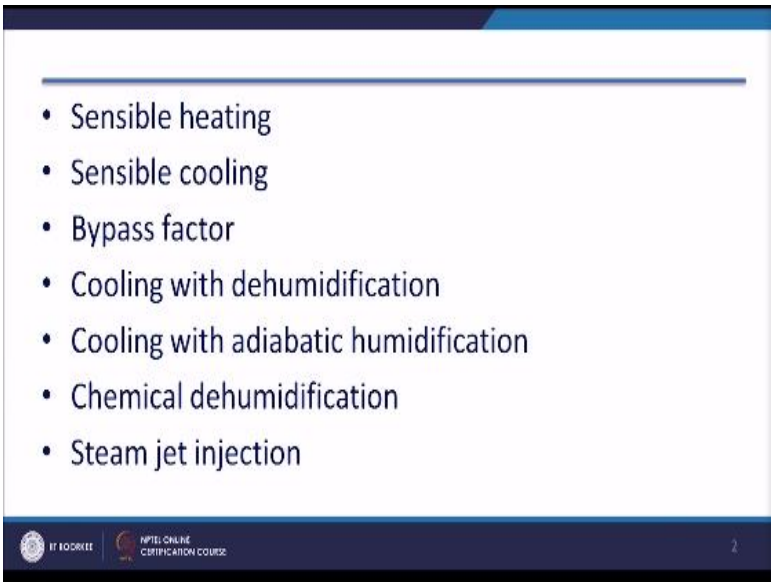

Now we will come to the cooling dehumidification now cooling with dehumidification I have taken earlier also I have taken one example where the outside temperature is 40 degree centigrade.

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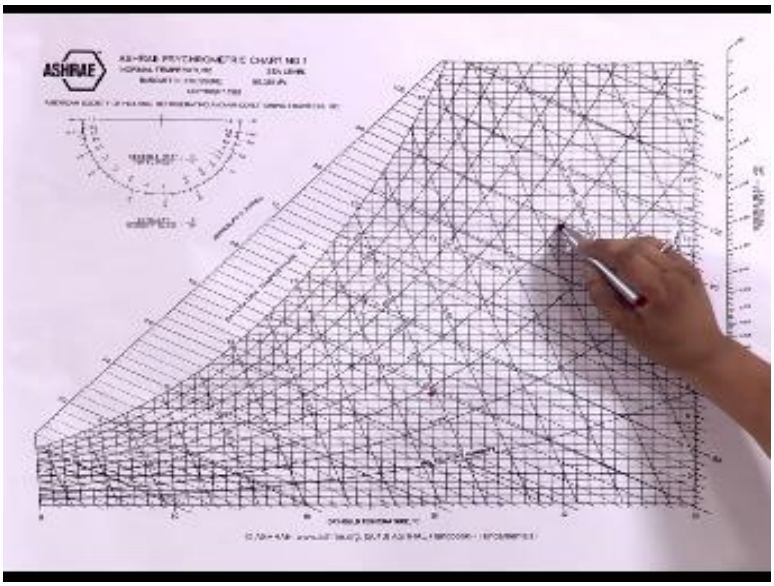

And the relative humidity is 40 percent or let us say it is 50 percent, so we will take outside air temperature that is very typical of North Indian temperature outside temperature is 40 degree centigrade DBT.

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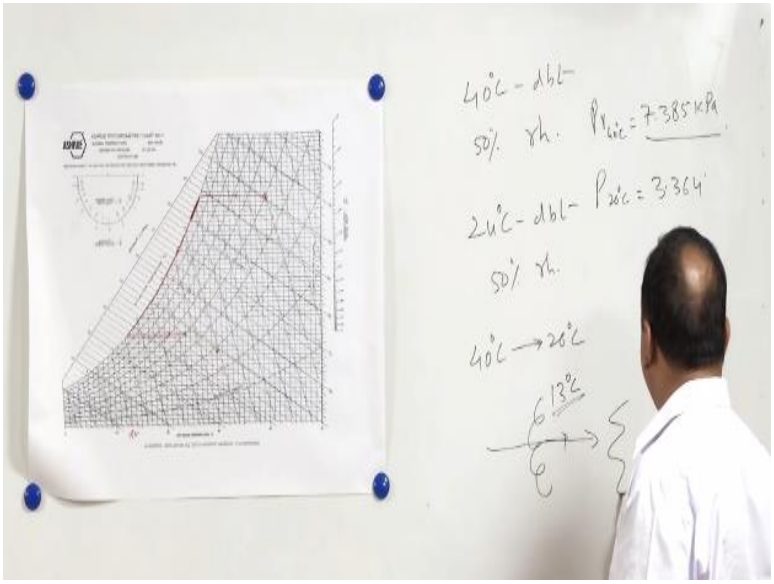

And 50 percent relative humidity, now this state can be shown on the psychometric chart here 50 percent r relative humidity this is state 1, now I want to have I mean my room temperature has 24 degree centigrade now this has to be reduced to let us say 24 degree centigrade DBT and let us say 50 percent RH but what happens when I do sensible cooling when I do the sensible cooling in that case.

This is sensible cooling so when the sensible cooling is done when the sensible cooling is done the temperature is reduced to five six seven eight 27.5 five degree centigrade and air is 100 percent saturated, I do not get 24 degree centigrade it means the air available at 40 degree centigrade and 50 percent RH if I do sensible cooling I cannot attain 24 degree centigrade temperature.

Now in order to attain 24 degree centigrade temperature I will have to come to this line and humidification has to be done I cannot maintain constant humidity ratio, so dehumidification has to be done so when the 100 percent saturation is attained 100 percent saturation means relative humidity is 100 percent is equal to PV/ PVS and PV = PVS it means the partial pressure of the vapor at this state when it is hundred percent is 7.385 kilo Pascal.

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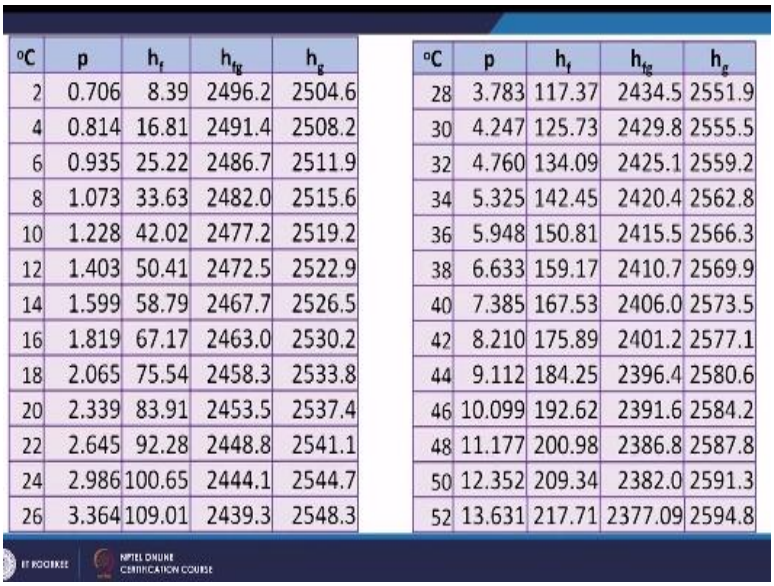

°C	p	h_f	h_{fg}	h_g
2	0.706	8.39	2496.2	2504.6
4	0.814	16.81	2491.4	2508.2
6	0.935	25.22	2486.7	2511.9
8	1.073	33.63	2482.0	2515.6
10	1.228	42.02	2477.2	2519.2
12	1.403	50.41	2472.5	2522.9
14	1.599	58.79	2467.7	2526.5
16	1.819	67.17	2463.0	2530.2
18	2.065	75.54	2458.3	2533.8
20	2.339	83.91	2453.5	2537.4
22	2.645	92.28	2448.8	2541.1
24	2.986	100.65	2444.1	2544.7
26	3.364	109.01	2439.3	2548.3

°C	p	h_f	h_{fg}	h_g
28	3.783	117.37	2434.5	2551.9
30	4.247	125.73	2429.8	2555.5
32	4.760	134.09	2425.1	2559.2
34	5.325	142.45	2420.4	2562.8
36	5.948	150.81	2415.5	2566.3
38	6.633	159.17	2410.7	2569.9
40	7.385	167.53	2406.0	2573.5
42	8.210	175.89	2401.2	2577.1
44	9.112	184.25	2396.4	2580.6
46	10.099	192.62	2391.6	2584.2
48	11.177	200.98	2386.8	2587.8
50	12.352	209.34	2382.0	2591.3
52	13.631	217.71	2377.09	2594.8

So partial pressure of the vapor at 40 degree centigrade is 7.385 kilo Pascal further cooling will reduce the temperature and vapor will remain saturated, it means suppose 42 we cool it upto 30 or 25 degree 25 degree, right. So when 40 to 25 or here in this case we can go to let us say 26 if we cool from 40 to 26 40 degree centigrade to 26 degree centigrade the partial pressure at 26 degree centigrade is 3.364.

Now this is 26 degree then partial pressure is 3.364 so partial pressure of vapor has reduced it means it means the sum of the vapor has been removed from the air and that is visible from here also the moment we come to 26 degree it is here 26 degree 26 degree, right. The specific humidity has reduced drop of water vapor per kg of dry air has reduced; it means water has precipitated from air.

Now we want to have 24 degree centigrade so we will cool it up to 24 but when we cool it up to 24 the RH is not attained we need RH 50% here RH is 100% and we cannot move in a vertical direction in the psychometric chart you can move in a horizontal direction but movement of the vertical direction all of a sudden you going to draw all the I mean certain amount of water from the vapor without realizing any process.

So what we can do we can further cool it, so air can be further cooled up to this point that is 30 degree centigrade so air can be further cooled up to 13 degree centigrade and in this process in this process the partial pressure of the vapor will keep on reducing it will come close to the 1.5 kilo Pascal after attaining this 13 degree centigrade here the vapor is again heated, so this is known as reheating of air.

And the only then we can get this state of 24 degree centigrade dry volt temperature and 50 percent RH, now I am repeating if outside air is available at 40 degree centigrade dry volt temperature and 50 percent relative humidity, maintaining the same relative humidity if I want to reduce the temperature up to 24 degree centigrade I cannot simply term from this point to this point for this purpose first of all sensible cooling has to be done.

Till the air gets saturated, once the air gets saturated with water then when we further cool the air the water will start precipitating because here the amount of water in air is constant during the sensible cooling but the moment dehumidification takes place the water gets starts getting precipitated and it is cooled not only up to 25 because if we cool up to 25 degree centigrade we will be getting air which is 100% saturated.

But we need air at 50 percent saturation or a rate of humidity so further cooling is required up to 13 degree centigrade and then heating will be done, so the process the arrangement will be something like that something like this which may sound very strange then initially there is a cooling coil air is blown, cooling coil is at a temperature of if there is no bypass factor then it is a temperature of approximately 26 and a half degree centigrade.

This is 26 and a half degree centigrade this I have taken from here then not 25 not 25 this is twenty five, twenty six, twenty seven, twenty eight, 27.5 to 25, 26, 27, 27.5 not 26 27.5 degree centigrade okay and then further cooling is taking place here on the coil so coil temperature is not 27.5 it is maintained at 13 degree centigrade, so the air is blown over a coil which is maintaining at thirty degree centigrade.

And then this air which is emerging from this coil is heated up to twenty four degree centigrade and that is how the vapor at this state of 50 percent relative humidity is attained, now practically what we do we simply join this, this is a this is a imaginary process line and sometimes for the sake of convenience of the calculations these two lines these two points are joined these two points are joined together. You must have seen the desert coolers or simple coolers in the market so coolers have an exhaust fan in the middle.

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Surrounded by the wet pads and when this exhaust fan sucks air from these wet pads then air gets cooled and it is humidified and sometimes it is humidified to the extent then you feel very uncomfortable in such an environment, so this process is followed at constant wet bulb temperature line, suppose outside temperature is 40 degree centigrade or 35 degree centigrade and relative humidity 40 degree centigrade.

And a relative or 40 degree centigrade let us say 40 degree centigrade and relative humidity is 10 percent or outside environment is 35 degree centigrade and relative humidity is 20 percent, now in this case when the temperature is 35 degree centigrade relative unit is 20 percent cooling with

adiabatic humidification line will follow this wet bulb temperature line and it can go up to 100 percent saturation.

So is the case with the 40 percent this will also follow this line, right and when the efficiency of the system is 100% you will be getting this temperature at hundred percent humidification, now effectiveness of this is measured by suppose this is temperature t1 this in this process a adiabatic communication process this is temperature t1 this is temperature t2, so100% efficiencies you get 100% of this.

Suppose evaporator is 90 percent efficient you will be getting or eighty percent efficient you will be getting temperature t3 here or temperature maybe somewhere here, so this process is very useful in the climate where the relative humidity is low and temperature is high for example desert climate, another is chemical dehumidification.

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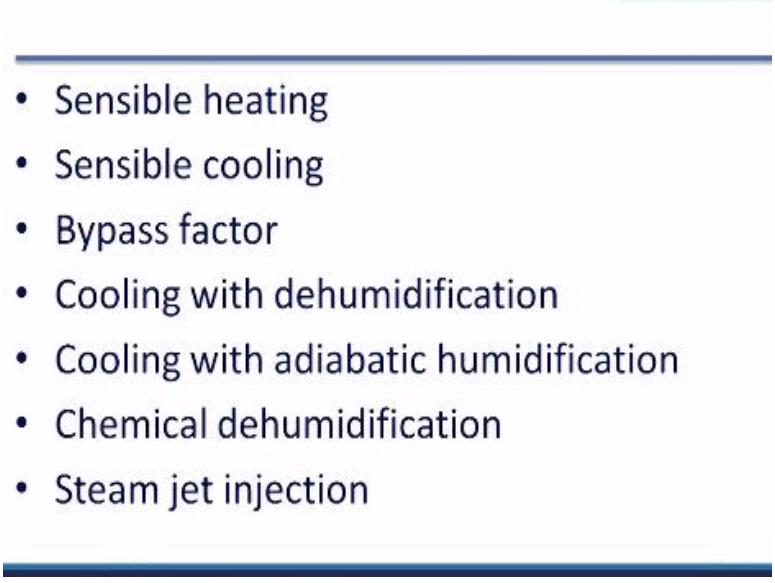

Now chemicals are also used to absorb vapor from the air like silica gel, during this process chemical dehumidification process that is the reverse of this process if you do the chemical dehumidification the process.

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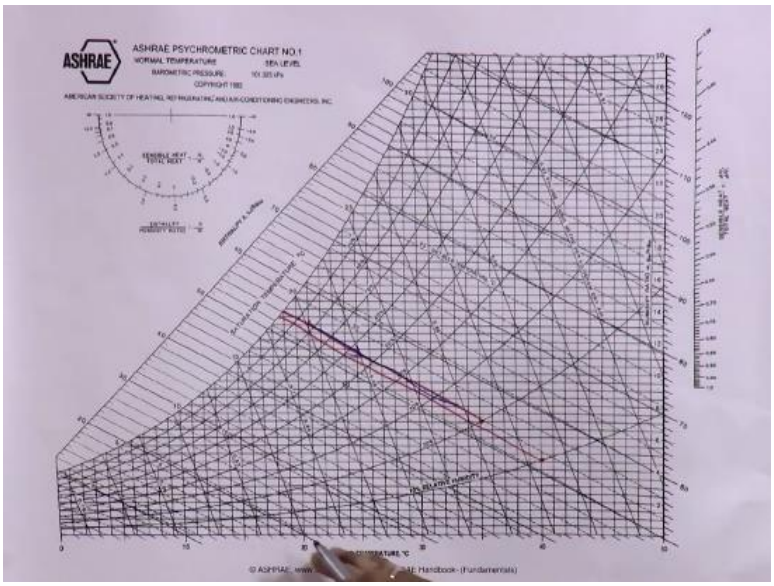

Will be reverse this process, so this is causes this causes dehumidification in heating, heating of the air and because the vapor present in the air is transformed into the liquid form and latent heat of the vapor is added to the enthalpy of air and that is where there is a rise in temperature, so for this dehumidification process it is reverse of the humidification there is a rise in dry bulb temperature.

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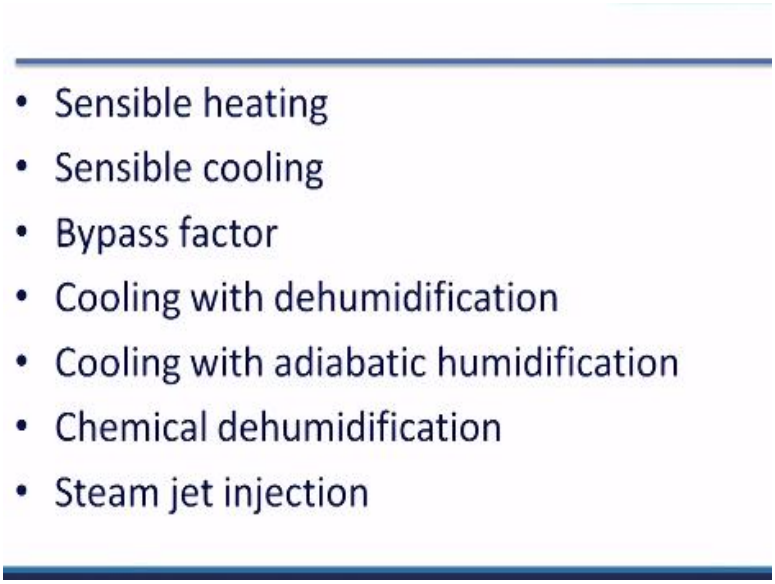

Steam jet injection, now steam can also be used for humidification of air, suppose I want to increase humidity at a particular temperature.

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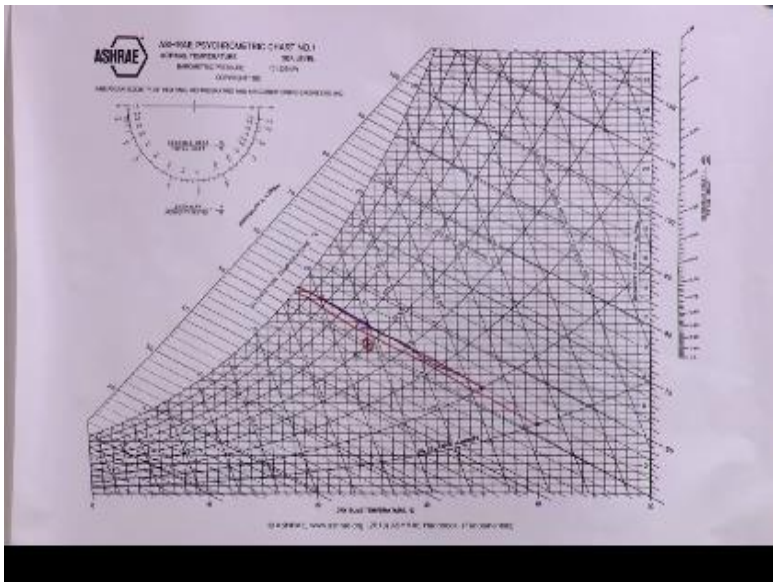

Let us say a temperature of 25 degree centigrade if I want suppose25 degree centigrade and 50 percent relative humidity, state is here I want to further improve the humidity up to70% or 80% I can inject steam available at 25 degree centigrade into the system or steam at higher temperature can also be injected in that case the temperature of air will slightly increase but steam is a very good medium of increasing humidity of air without increasing humidity of air with very low temperature rise of the air.

So these are certain processes we have discussed these are elementary processes in an air conditioning system some more processes are to be discussed in the coming lecture this is all for today, thank you.

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Acknowledgement

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Director, IIT Roorkee

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Production Team

Neetesh Kumar

Jitender Kumar

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